

# Planning & Priority Setting for Basic Research

Presented to the National Academy of Sciences, 5 May 2010

**PE 0601153N – Defense Research Science**

**PE 0601103N – University Research Initiative**

**PE 0601152N – In-House Laboratory Independent Research**

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# Discovery & Invention

## KNOWLEDGE

*Develop Naval-relevant fundamental knowledge*

Expand the boundaries in traditional Naval interest research areas

Examine new research directions for future Naval needs

Encourage risk-taking to seek scientific breakthroughs

## TRANSITIONS

*Provide the basis for future Navy and Marine Corps systems*

Ensure research relevancy to Naval S&T strategy

Transition promising Basic Research to applications

Use knowledge (even failures) to reduce risk in acquisition

## PEOPLE

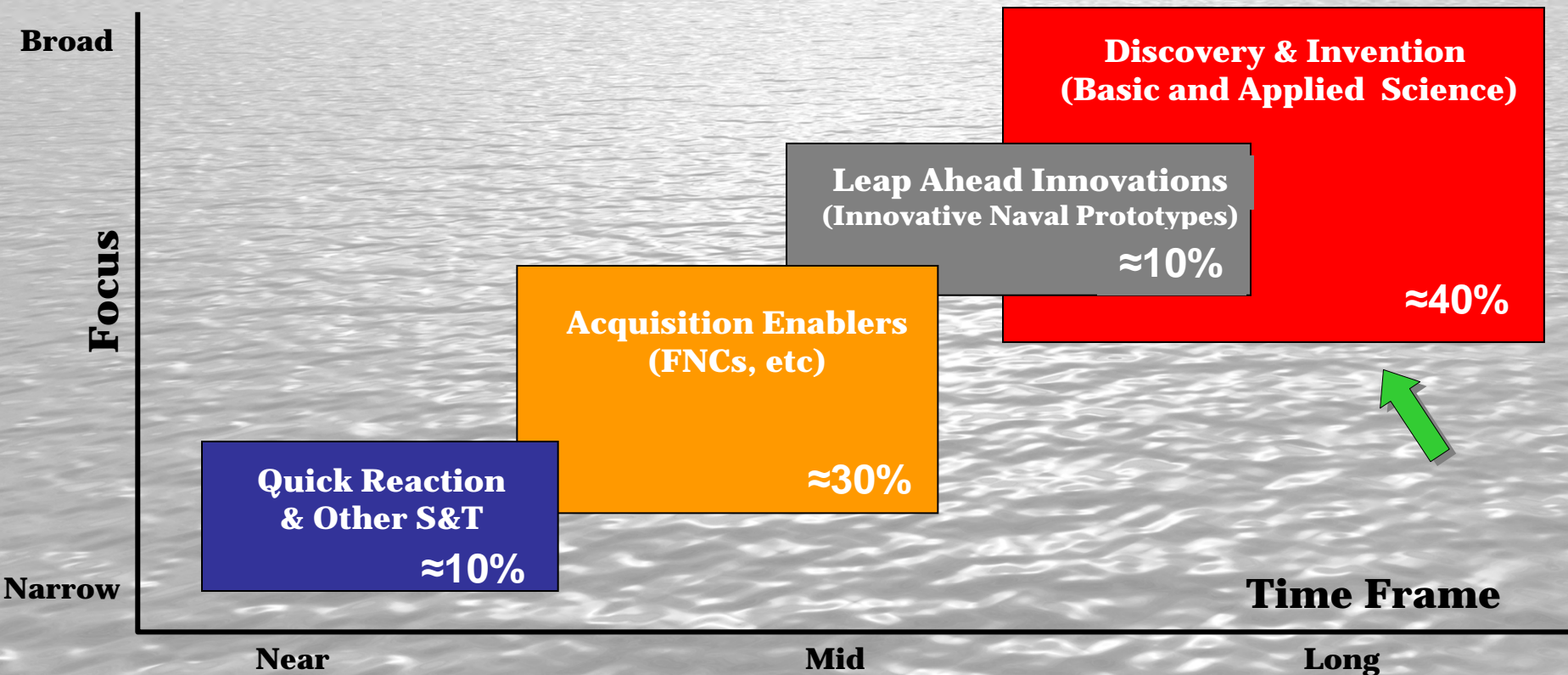
*Maintain the health of the Defense Scientist and Engineer workforce*

Develop and nurture future generation of DoD researchers and engineers  
Ensure continued U.S. advantage in intellectual capital

Maintain unique/essential research infrastructure



# S&T Portfolio Focus to Meet Navy Needs



Quick Reaction

- Tech Solutions
- Experimentation
- MC S&T (MCWL, JNLW, etc.)

Acquisition Enablers

- Future Naval Capabilities
- Warfighter Protection
- Capable Manpower
- LO/CLO

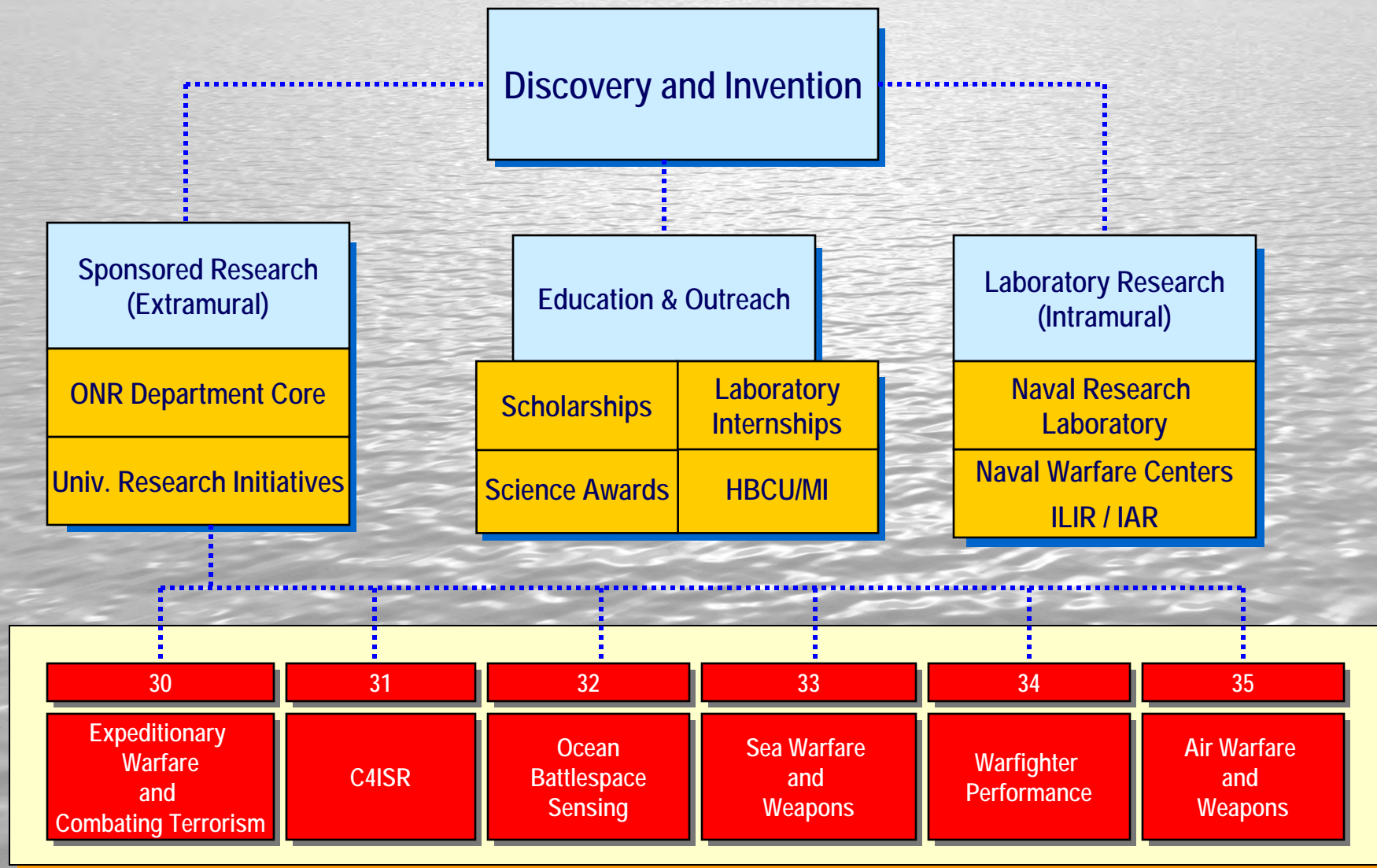
Leap-Ahead Innovations

- Innovative Naval Prototypes
- NSPs
- Swampworks

Discovery & Invention

- Basic & Early Applied Research
- National Naval Responsibilities
- Education Outreach HBCU/MI

# D&I Components



# Naval S&T Taxonomy





- Autonomous Sciences
- Bio-Inspired Sciences
- Cognitive, Neural and Training Technologies



- Information Fusion & Decision Sciences
- Quantum Computing
- Information Assurance
- Materials
  - Metamaterials
  - Integrated Computational Material Sciences
  - Nano-Manufacturing
- Counter IED Sciences





## PE 0601153N – Defense Research Science

- DRS portfolio objectives are:
  - 1) Develop scientific and fundamental knowledge;
  - 2) Provide the basis for future Navy and Marine Corps systems; and
  - 3) Maintain the health of the defense scientist and engineer workforce.

## PE 0601103N – University Research Initiatives

- URI funds promising new research, stimulates innovation, and attracts outstanding researchers to naval-relevant research projects.

## PE 0601152N – In-House Laboratory Independent Research

- ILIR/IAR programs are focused on providing quality research and revitalizing the competency of the technical workforce at the Navy Labs.



# D&I Investment Strategy

## Demand Signal

- Scientific innovations & Basic Research to support:
  - **Naval Focus Areas**
    - Research Core Areas
    - Research Sub-Areas
    - National Naval Responsibilities (NNRs)
  - **Naval Warfare Enterprises**
  - **Global Innovation & Threat**

*Input*

## Strategic Alignment

- Specialized Programs:
- Multidisciplinary University Research Initiative (MURI)
  - In-House Laboratory Independent Research (ILIR)
  - Young Investigator Program (YIP)
  - Basic Research Challenge (BRC)
  - ONR 6.1 Core Programs
  - **ONR 6.2 Core Programs**
  - **Independent Applied Research (IAR)**

*Input*

## Review & Selection for S&T Programs

Criteria:

- Defense Science & Technology Advisory Board (DSTAG)
- Defense Basic Research Advisory Group (DBRAG)
- Peer Review
- **Program Review & Monitor**
- **Potential for transition to FNC/ INP/ Program Offices**

6.1 Basic Research  
6.2 Early Applied Research

## S&T Output

*Measuring Success:  
Knowledge, Transitions & People*

- Publications (Refereed papers)
- Patents & Licenses
- Citations

- 6.1 to 6.2 transitions,
- **Transition to INP & FNC**
- **Transition to Program Offices**

- STEM Program
- Advanced Degrees Completed
- Participants Joining Naval Warfare Labs

***Assess 6.1 Basic Research portfolio in terms of S&T Quality, Scientific Breakthroughs & Contributions, and Program Risk to determine strengths/weaknesses of the current portfolio.***

- Every ONR basic research program will be peer-reviewed during the 2<sup>nd</sup> to 3<sup>rd</sup> year from its inception.
  - ONR Program Officers will schedule an off-site review of their programs
  - ONR Program Officers will convene Peer Review Boards comprised of recognized scientific/technical experts
  - Principal Investigators will present their work
  - 03R will compile Review Panel comments for each program
  - Director of Research, Department Head, and Program Officer will review Panel comments and adjust program as needed
- Peer Review of basic research programs began with Code 32 Environmental Optics program in Feb 2010.
- ONR Peer Review Instruction is being circulated for comment.



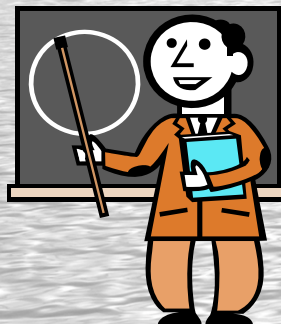
## September

## December



Departments identify  
program issues  
requiring funding  
changes (up or down)

Over several days,  
departments give  
briefings on each  
program issue



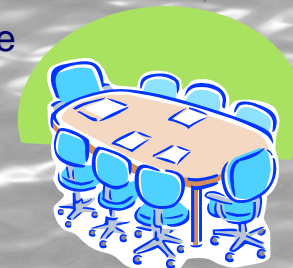
Over several more  
days, ONR directors &  
department heads  
assess impacts of IBR  
briefings on their own  
portfolios and submit  
recommendations

Designated Officials  
vote on IBR issues



Voting officials meet and decide which issues are  
highest priority and how to fund:

- Reallocate money within a department
- Reallocate money across organization
- Request new money (unlikely)



## Basic Research Challenge (BRC)

- Select and fund promising research programs in new areas not addressed by the current basic research program.

## Historically Black Colleges and Universities and Minority Institutions

- Increase the quantity and quality of minority scientists and engineers

## Young Investigator Program (YIP)

- Identify and support academic scientists and engineers who have received Ph.D. or equivalent degrees within the last five years

## ONR Core 6.1 Programs

- Basic research programs executed by ONR program officers



## Basic Research Challenge

- Competitively funds promising research programs in new areas not currently addressed by the Basic Research program.
- Stimulates new, high-risk Basic Research projects in multi-disciplinary and Departmental collaborative efforts.
- 4-year grants, \$1.5M/year
- FY2010 Basic Research Challenge BAA topics:
  - Biologically-inspired Intelligent Metamaterials
  - Computing with Natural Language
  - The Micro-physics of a Liquid-Solid-Gas Interaction
  - Acoustical Uncertainty due to Marine Mammals and Fish

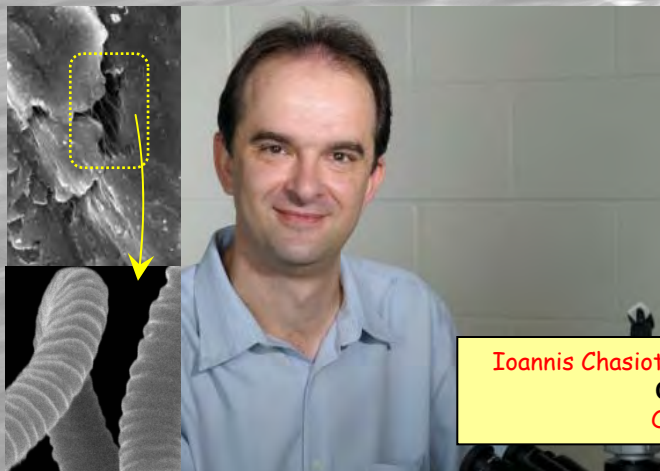
## HBCU/MI Programs

- HBCU/MI Matching Funds for Research – Provided to the ONR S&T codes as an incentive to promote more HBCU/MI participation in naval research.
- Research and Education Partnership Program (REPP) –Students are exposed to Navy civilian S&E careers through summer internships at Navy laboratories.
- HBCU/MI Summer Faculty – S&E faculty members participate in research at Navy laboratories for 10 weeks during the summer.

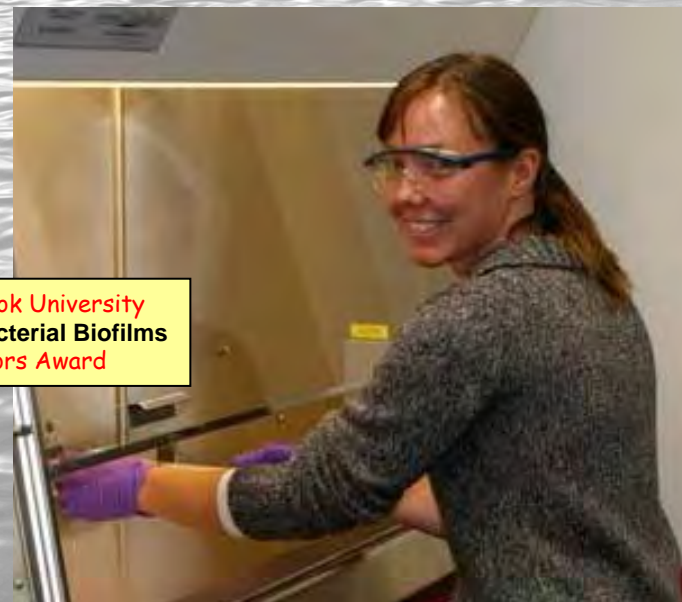


## Young Investigators Program (YIP)

- Attracts outstanding new faculty researchers to naval-relevant research
- Encourages their teaching and research careers
- 17 awards In FY2010
- The Young Investigator Program (YIP) process
  - Broad Agency Announcement in October
  - Proposals are due January via grants.gov
  - Grants begin in June
  - Funding available: \$7.5M over three years



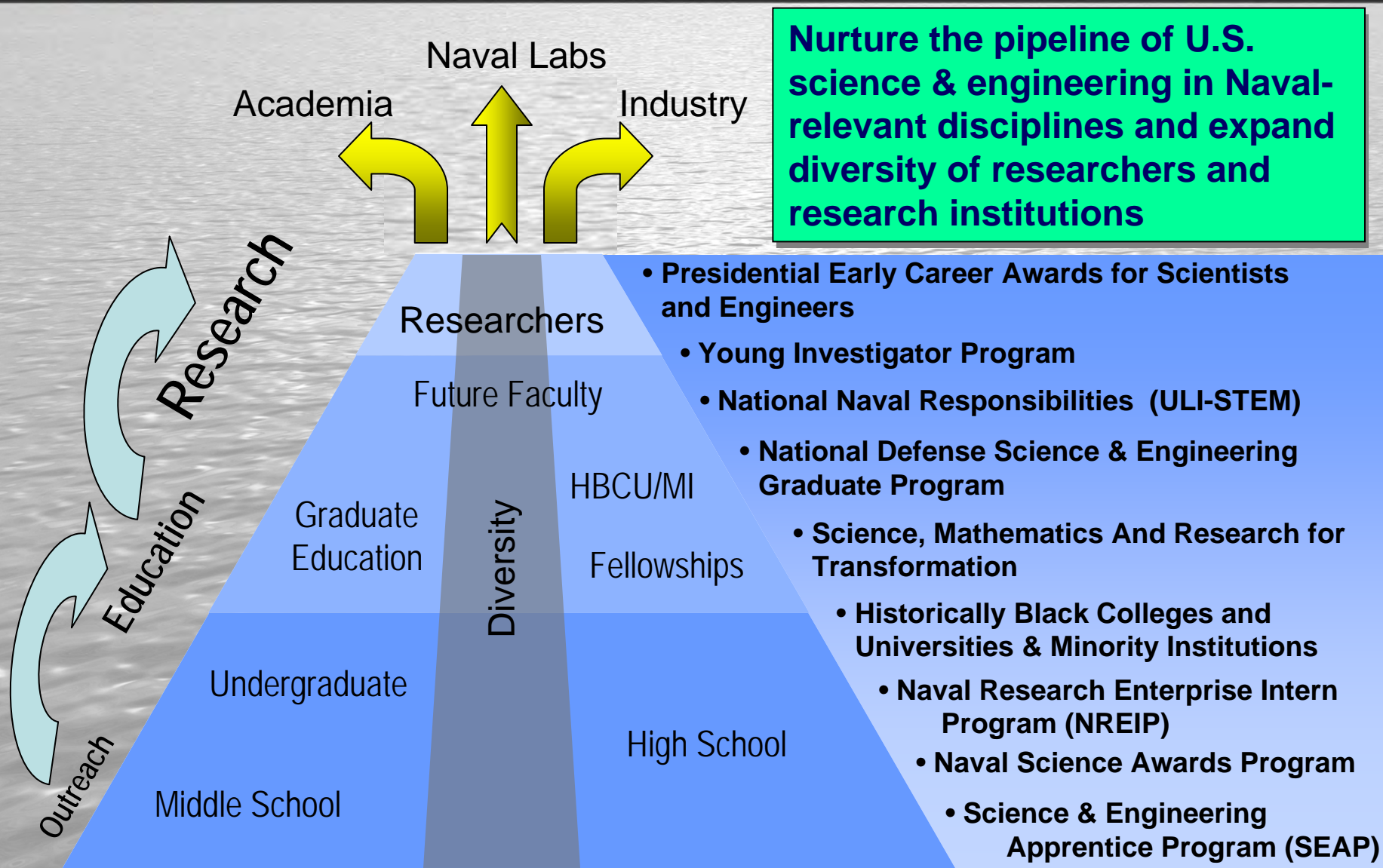
**Ioannis Chasiotis, University of Illinois at Urbana-Champaign**  
**Continuous Carbon Nanofibers**  
**ONR Young Investigators Award**



**Elizabeth Boon, Stony Brook University**  
**Nitric Oxide Signaling in Bacterial Biofilms**  
**ONR Young Investigators Award**



# Education and Outreach



Data as of March 15, 2010

FY 09 Investment in STEM: \$39.7M *[plus an additional \$108M invested in University Research Initiatives ]*

- 156 programs
- Conducted by 24 Naval organizations
- Reaching more than 59,000 students annually *[plus an additional 100K through science fairs]*
- Participants come from all 50 states and several territories
- Portfolio covers all stages of the STEM pipeline:
  - K-12 Outreach and Awareness
  - Middle School—Hands-on Learning
  - High School—Internships and research experiences
  - Undergraduates, Masters and Doctoral Students: Employment, Scholarships, Fellowships and Internships
  - Faculty research experiences
  - Naval STEM employees: Professional development
  - Professional development for high school teachers



# Defense Research Sciences FY 10 Funding Summary

PE 0601153N

• Air, Ground and Sea Vehicles	\$52.3M
• Atmosphere and Space Sciences	\$30.0M
• Counter Improvised Explosive Device (IED) Sciences	\$22.7M
• Human Systems	\$16.6M
• Information Sciences	\$33.9M
• Materials/Processes	\$61.5M
• Medical/Biology	\$17.4M
• Ocean Sciences	\$80.9M
• S&E Education, Career Development and Outreach	\$26.4M
• Sensors, Electronics & Electronic Warfare (EW)	\$51.8M
• Weapons	\$18.5M
• Congressional Plus Ups	<u>\$17.1M</u>
TOTAL:	\$429.1M

## Defense University Research Instrumentation Program (DURIP)

- Funds (\$.5M to \$1M) will be used for the acquisition of major equipment to augment current or develop new research capabilities in support of DoD-relevant research.

## Multidisciplinary University Research Initiative (MURI)

- Teams of researchers investigating high-priority topics that intersect more than one technical discipline.

## Presidential Early Career Award for Scientists and Engineers (PECASE)

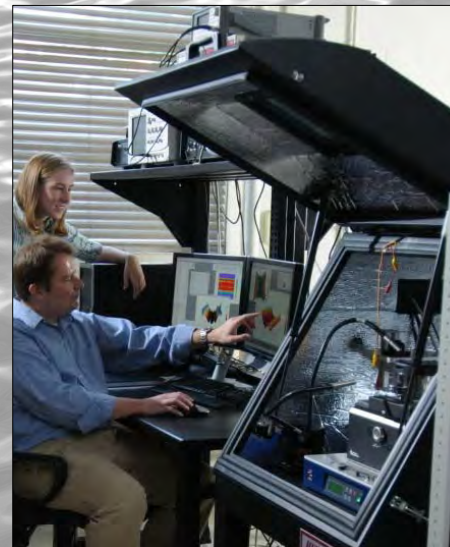
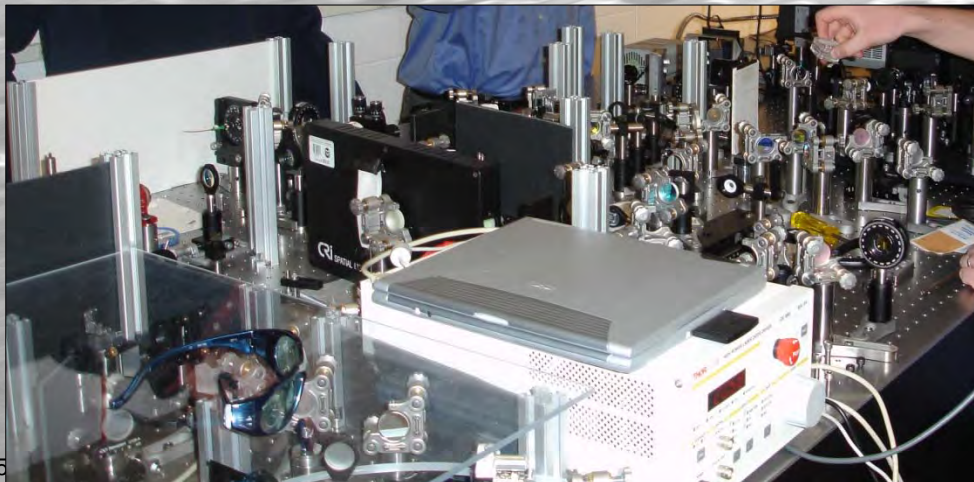
- Honors and supports the extraordinary achievements of young professionals at the outset of their independent research careers in science and technology.



## Defense University Research Instrumentation Program (DURIP)

supports university research infrastructure essential to high-quality Navy-relevant research

- Proposals may request \$50,000 to \$1,000,000
- Funds will be used for the acquisition of major equipment to augment current or develop new research capabilities
  - Over 260 proposals were submitted for FY2010
  - 61 proposals totaling approximately \$17.9M were recommended to DDR&E
  - Final awards were announced in March 2010

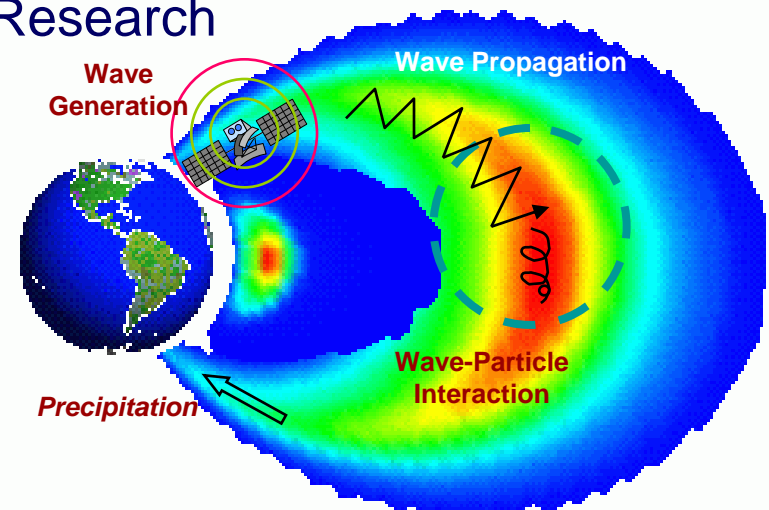
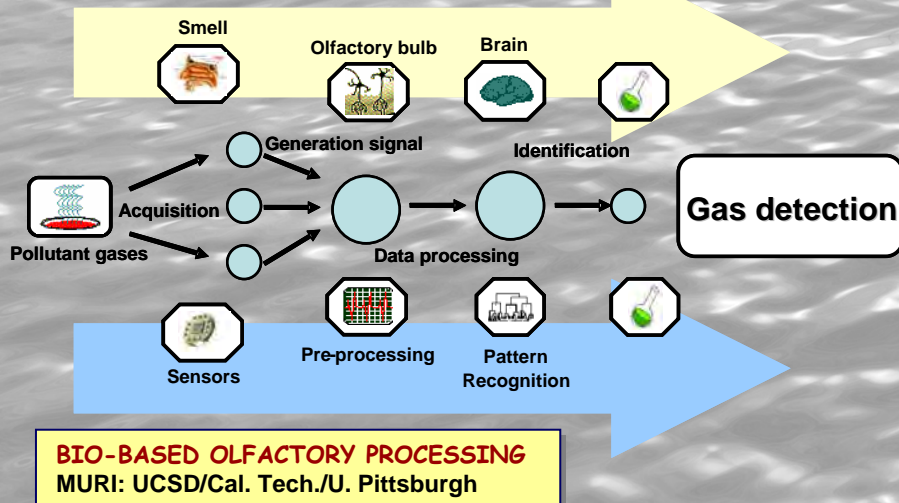
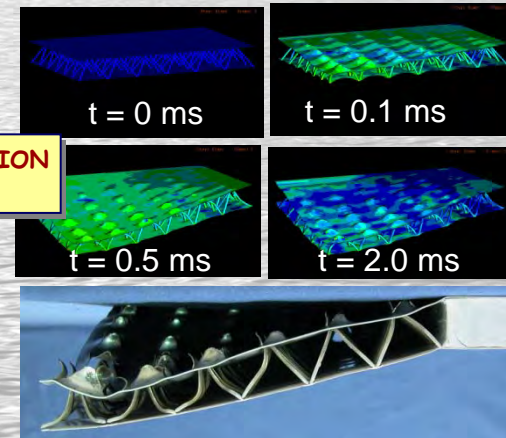




## Multidisciplinary University Research Initiative (MURI)

- Multiple institutions investigating high priority topics
- Stimulate innovations
- Accelerate research progress
- Expedite transition of results into naval applications
- Eight MURI grants were initiated in FY2009.
- For FY2010, proposals will be solicited in research areas determined by DDR&E Director of Basic Research

**MATERIALS APPROACH to FORCE PROTECTION**  
MURI: UVA/Harvard





## Presidential Early Career Award for Scientists and Engineers (PECASE)

- The PECASE award recognizes and honors outstanding scientists and engineers at the outset of their independent research careers.
- In FY2009, 15 ONR awardees were announced, selected for their work in the following areas:

- Chemistry
- Fluid Dynamics
- Distributed Learning
- Biomimetics
- Marine Mammals
- Modeling and Simulation

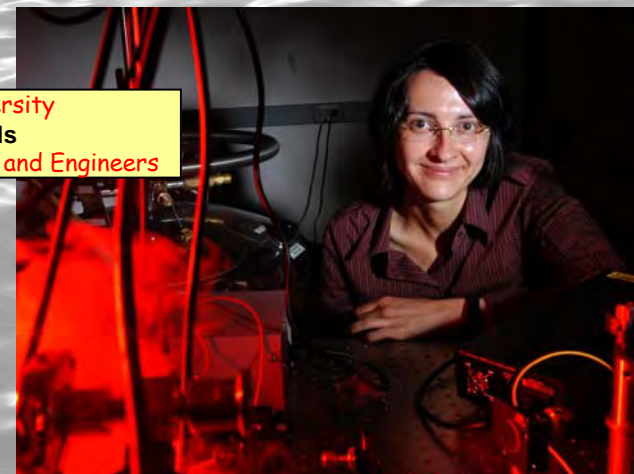


Randy Bartels, Colorado State University  
Precisely Tunable Optical Frequencies  
Presidential Early Career Award for Scientists and Engineers



Dr. Kelly J. Benoit-Bird, Oregon State University  
Predator effects on dense zooplankton aggregations  
Presidential Early Career Award for Scientists and Engineers

Prof. Jelena Vuckovic, Stanford University  
Quantum Dots in Photonic Crystals  
Presidential Early Career Award for Scientists and Engineers



# University Research Initiatives FY10 Funding Summary

## PE 0601103N

• Defense University Research Instrumentation Program	\$20.3M
• Multidisciplinary University Research Initiative (MURI)	\$72.4M
• Presidential Early Career Awards	\$6.3M
• Congressional Plus Ups	<u>\$3.2M</u>
TOTAL:	\$102.2M

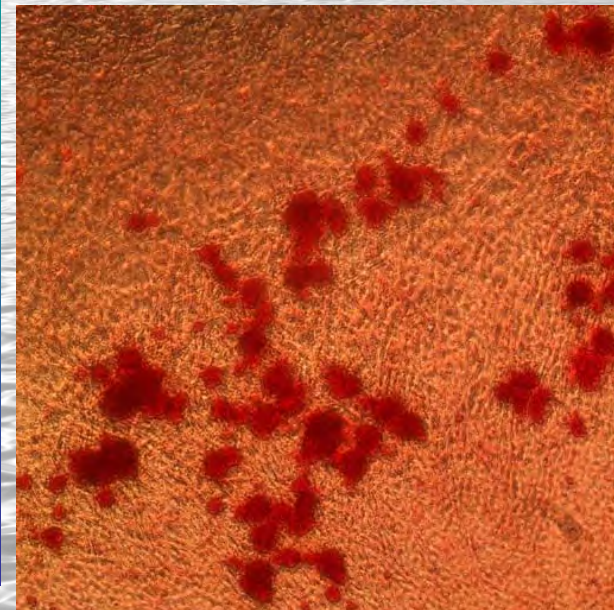


# In-House Laboratory Independent Research

- *Provides Navy laboratory directors the ability to invest in basic research of technical interest to meet laboratory mission elements*
  - *ONR funding provided through the Naval S&T for America's Readiness (N-STAR) program office*
  - *Broadens Navy S&T perspective to avert technological surprise*
  - *Provides means for PIs to interact more directly with academia on topics of interest*
- 
- Designed to develop and maintain a cadre of subject experts and technologists at the Navy Warfare Centers
  - Technical focus is determined by laboratory TD and CO as it relates to mission areas and responsibilities
  - All FY09 projects map to the Naval S&T strategic plan
- 
- ILIR provides funding for education & outreach programs
    - Virginia Demonstration Project for 7<sup>th</sup> graders (Congressional)
    - Science and Engineering Apprentice Program (High School)
    - Naval Research Enterprise Internship Program (BS, MS, PhD)

# Repair/Replacement of Damaged Tissue

- ONR-funded In-house Laboratory Independent Research (ILIR) effort at the Navy Medical Research Center is paving the way to
  - identify the factors which guide the differentiation of stem cells into tissues such as bone, fat, and muscle
  - develop treatments to reduce the incidence of abnormal bone growth in war-injured personnel
- Using functional genome profiling to identify changes in genetic markers associated with the transition from stem cells to committed progenitor cells



Bone cells (stained red) generated from cultured stem cells

***This ONR-funded cutting-edge research is part of a multidisciplinary effort to expand the horizons of regenerative medicine***



## PE 0601152N

• Advanced Materials	\$3.5M
• Electronics Sensor Sciences	\$2.6M
• Energy Sciences	\$1.4M
• Human Performance Sciences	\$2.2M
• Information Sciences	\$2.2M
• Naval Platform Design Sciences	\$1.5M
• Ocean/Space Sciences	\$4.6M
• Congressional Plus Ups	-
<b>TOTAL:</b>	<b>\$18.0M</b>

# Summary

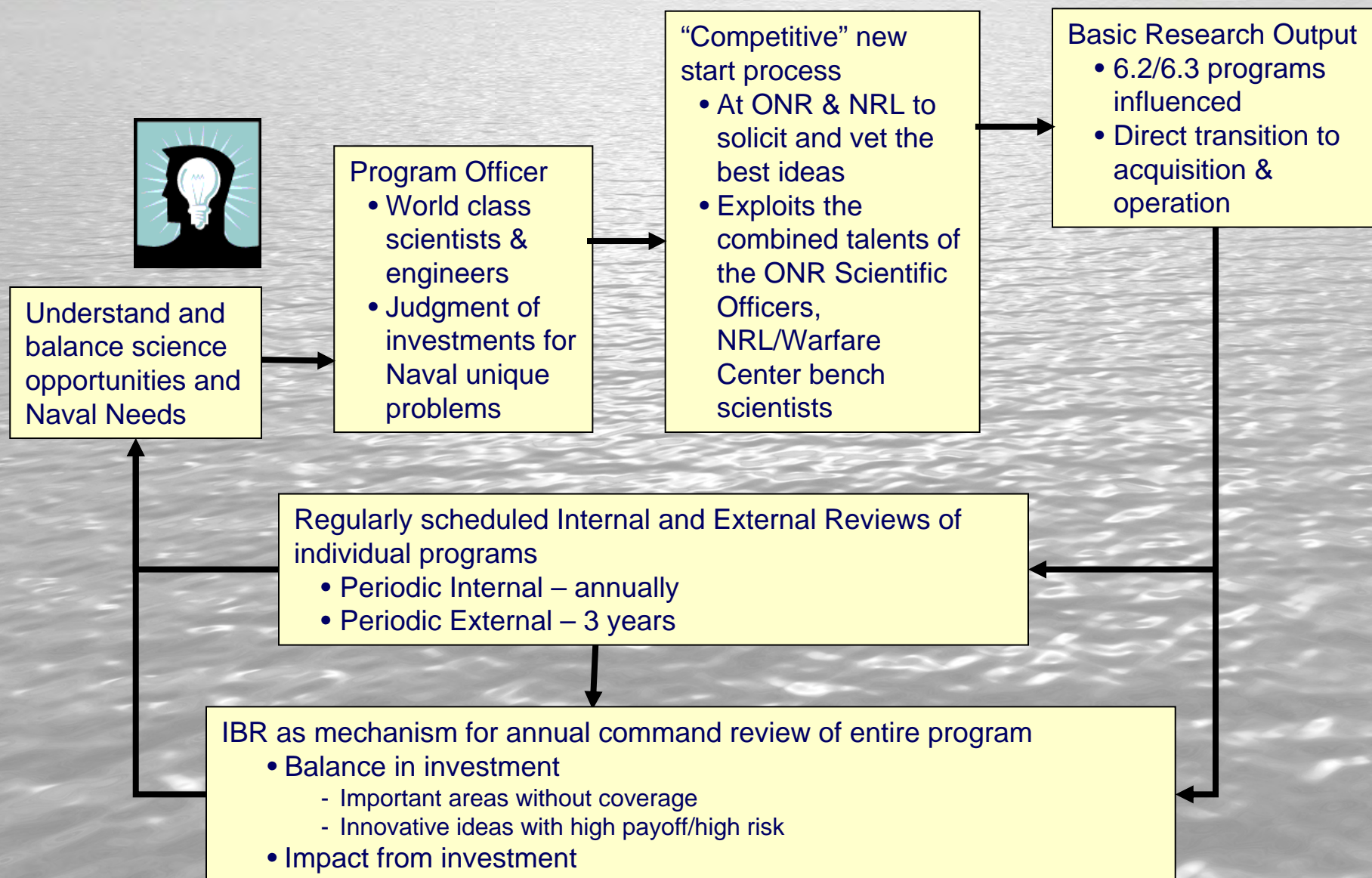
## *D&I is about*

- *Generating Knowledge...*
- *Creating the base for technology...*
- *Nurturing new/future researchers...*



# ***Backups***

# D&I Investment Process





# S&T Oversight Criteria

- Thrust areas are coordinated /aligned between ONR & NRL
- Thrust areas are not platform centric
- D&I goals
  - Create overwhelming technological superiority
  - Prevent technological surprise
  - Align future Naval capabilities with Naval S&T Grand Challenges, National Naval Responsibilities
  - Important and unique Naval S&T areas, and enables transition of product to Naval and Joint customers
- Leverage other agencies investment for Naval application
- Balance annually reviewed at Investment Balance Reviews (IBR)

# Context

## ONR

**Corporate Lab  
NRL**

Basic Research  
through  
Prototypes

### Performers:

- Academia
- Industry
- Other Gov Labs

### Sponsors:

- NSF
- DARPA
- NOAA
- Industry
- DoE
- Etc.

### Systems Commands:

- NAVSEA
- NAVAIR
- SPAWAR
- NAVFAC
- NAVSUP

**Warfare centers**

R&D Tech Demos  
Acquisition  
Procurement

**TRL 1-6**

**TRL 7-9**



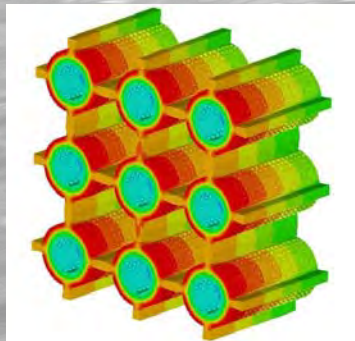


## *Examples of cutting-edge Basic Research at ONR (PE 0601153N)*

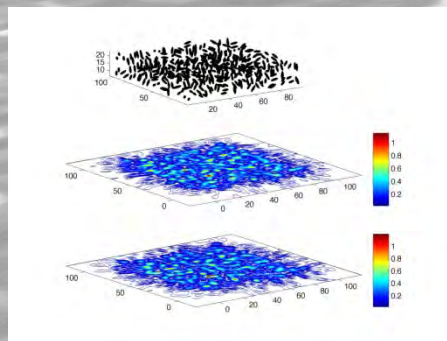
- Code 31: Fast Multipole Methods  
Reversible Hydrogenation of Graphene
- Code 32: Tropical Cyclone Formation and Intensity Forecasts  
Effects of Sound on the Marine Environment
- Code 33: Desorption Electrospray Ionization
- Code 34: Microbial Fuel Cell

- Adaptive, multi-scale methods reduce the cost of many-body interactions from  $O(N^2)$  to  $O(N \log N)$  with user-controlled precision
- Applicable to electromagnetics, gravitation, CFD, acoustics, elasticity, heat transfer, chemistry
- Provide orders of magnitude speedup over direct methods
- Integrated into numerous commercial codes in aerospace, automotive, semiconductor, and chemical industries

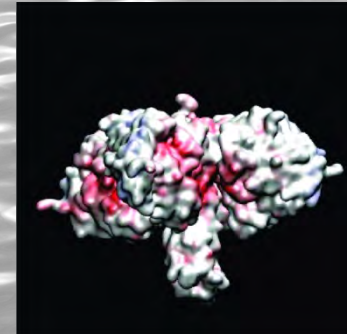
## Applications



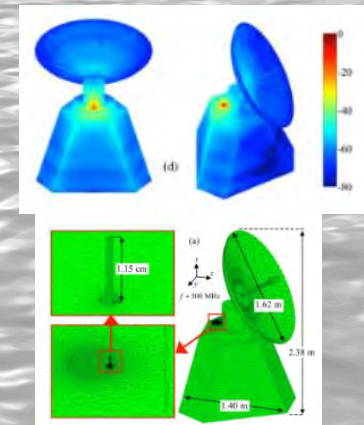
**Thermal analysis  
of fuel cells**  
(Y. Liu)



**Electromagnetics of  
microstructured materials**  
(Gimbutas, Greengard)



**Molecular  
electrostatics**  
(Lu, Cheng, Huang, McCammon)



**Radiation from  
multiscale structure**  
(E. Michielssen et al.)



# Reversible Hydrogenation of Graphene (ONR 31)

Graphane, a chemical derivative of Graphene

- Formed by attaching a hydrogen atom to each of the carbon atoms in the original graphene sheet
- Hydrogen alternates between above and below the sheet

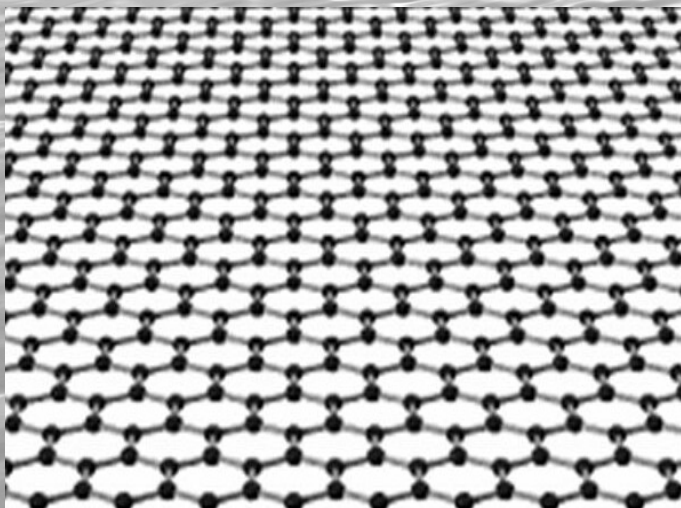
Graphene and Graphane have drastically different electronic properties

- Graphene is the best conductor known to man (at room temperature)
- Graphane is an electrical insulator

Graphene-Graphane reaction is entirely reversible

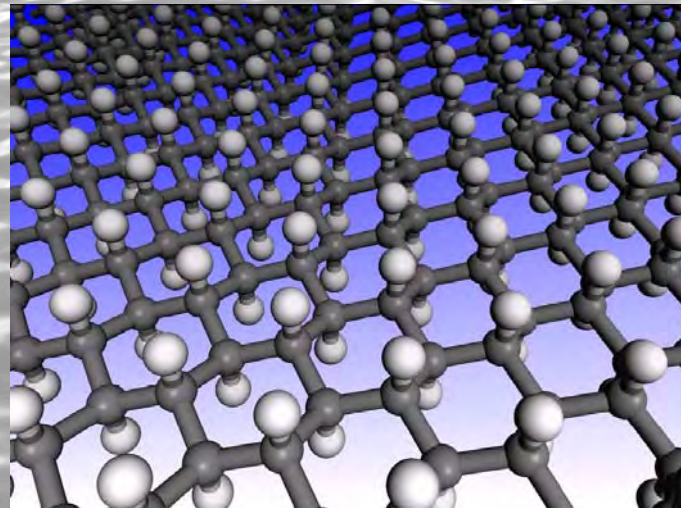
**New ways of constructing 2D electron devices and circuits**

GRAPHENE

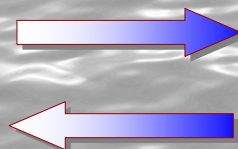


Single-layer 2D Carbon

GRAPHANE

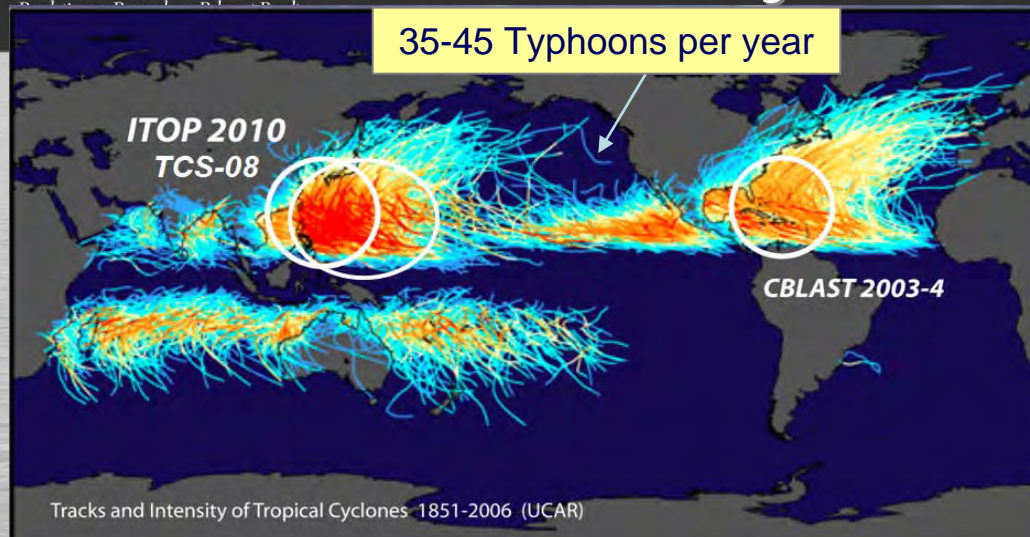


Single-layer 2D Hydro-Carbon



# Tropical Cyclone Formation & Intensity Forecasts (ONR 32)

35-45 Typhoons per year



## Basic Research Efforts

### CBLAST (2003-2004) Field Program

- Confirmed coefficient of drag drop at high winds
- Demonstrated need to include waves in coupling physics
- Developed new class of air deployable sensors to observe upper ocean in high wind conditions

*In the Western Pacific, improvement of typhoon intensity forecasts is the #1 METOC requirement*

### ITOP 2010 Field Program will

- Examine cold wake evolution and decay for ASW
- Investigate interaction of storm, wake, and eddy fields
- Field new sensors for tropical cyclone conditions

2004-2012

**6.2 Transition: Enhance the Coupled Atmosphere-Wave-Ocean Model for Operational Evaluation**

2009-2012

**Joint 6.2/6.4 Rapid Transition Program: Collaborate with operational centers to transition research model to full operational status in 3 years for all typhoon, cyclone, and hurricane forecasts for global Fleet support**

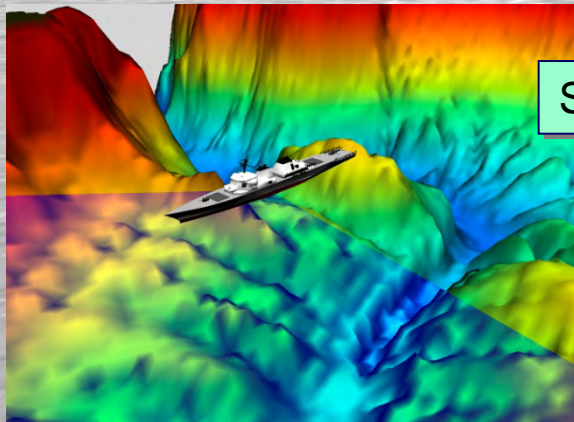
### TCS-08 Field Program (2008)

- Observed storm formation in WestPac
- Characterized storm interaction with ocean eddy field
- New technology to observe development of convection



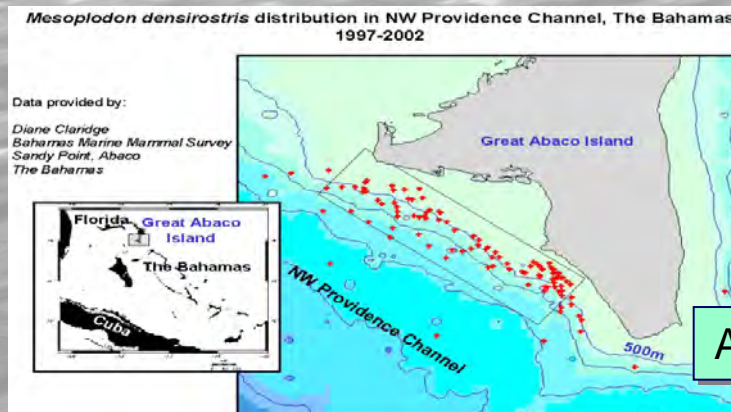
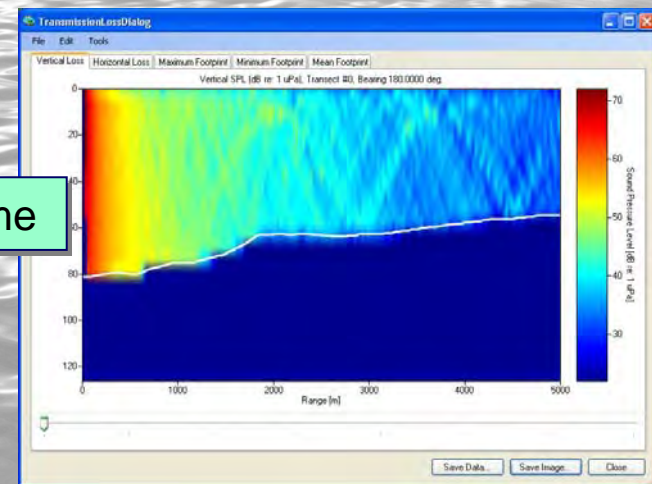
# Effects of Sound on the Marine Environment (ONR 32)

- A 6.1 environmental simulation and modeling 'engine' developed to determine how sound propagates and interacts with marine mammals
- Multidisciplinary acoustic model using state-of-the-art science to estimate risk to marine life from sound exposure
- Component of single Navy environmental effects model



Ship track with bathymetry

Sound field in 3D and over time



Animal distributions, behaviors, & exposures

# Desorption Electrospray Ionization (ONR 33)

Establish mass spectrometry (MS) as a technique for routine in-situ chemical analysis

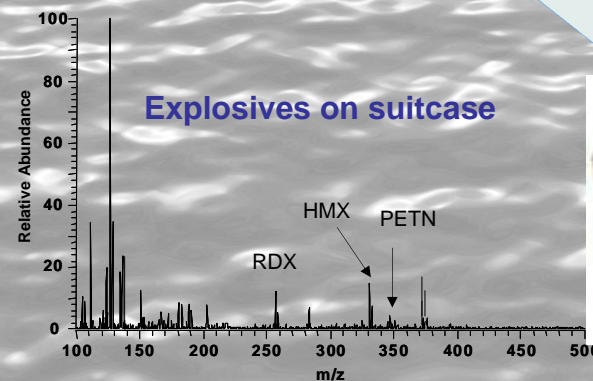
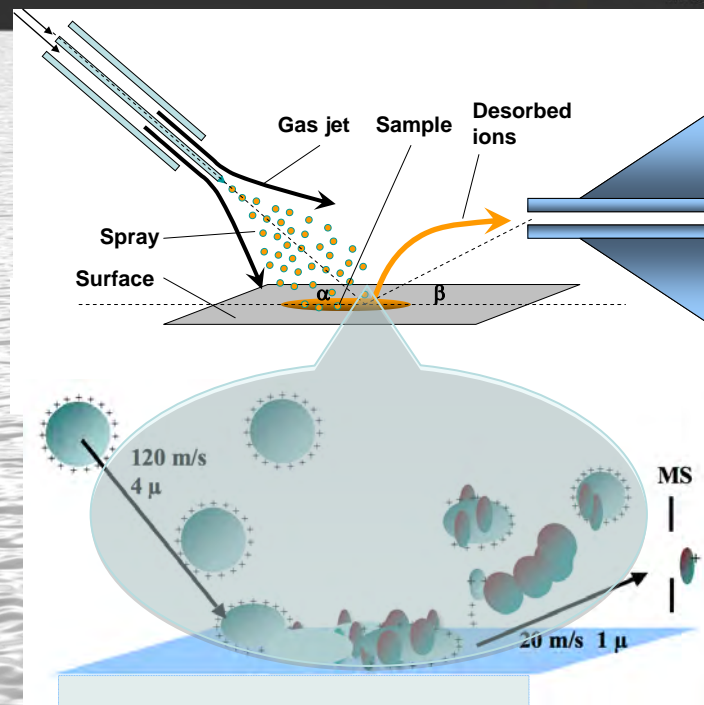
- Explore analytical performance for various trace organic chemicals

Develop interface between the mass spectrometer and the environmental sample

- Simulate the desorption ionization process
- physico-chemical measurements to elucidate ionization and ion transport mechanisms

Implement DESI technology on portable MS

- Develop analysis-at-a-distance capability



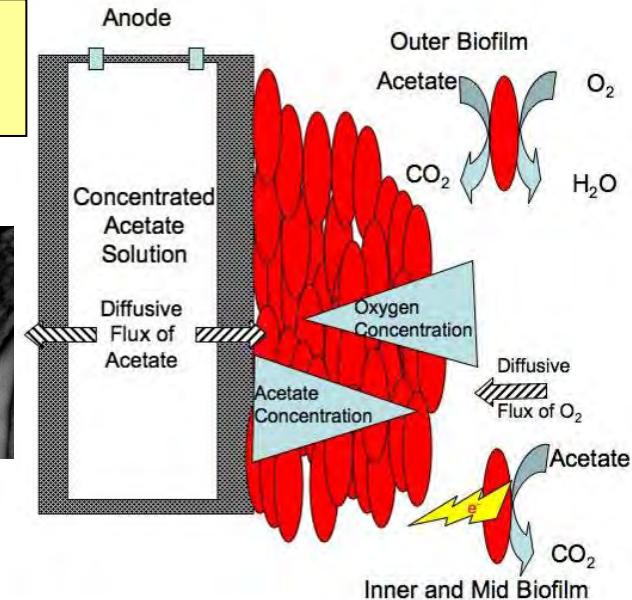
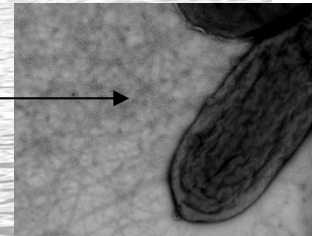


# Microbial Fuel Cell (ONR 34)

MFCs generate small amounts of electricity and are useful for powering undersea sensors and other small devices.

## ONR Research has

- Identified a strain of *Geobacter* bacteria produce protein-based 'nanowires' which conduct electricity
- Showed that bacterial 'nanowire' structures conduct electricity in biofilms
- developed MFC design that allows sustained operation in air, even with bacteria that can't tolerate air
- Developed strategies for evaluating which bacterial genes are important for electricity production
- Gained understanding of electron transfer reactions at the cathode which will allow optimization of MFC



- MFC now operable in air for extended periods
- Fundamental knowledge of microbial physiology enables improved power and efficiency
- MFC is non-hazardous (no H<sub>2</sub> gas, no explosive reactants)
- Time Magazine named MFC one of the Top 50 Inventions of 2009